Aircrew dosimetry: monitoring and operational services in France

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European Regulation following IRCP recommandations

Article 42, directive 96/29/EURATOM may 13th, 1996

«Each Member State shall make arrangements for undertakings operating aircraft to take account of exposure to radiation of air crew who are liable to be subject to exposure to **more than 1 mSv per year**. The undertakings appropriate measures, in particular:

- *to assess the exposure of the crew concerned,*
- *to take into account the assessed exposure when organizing working schedules with a view to reducing the doses of highly exposed aircrew,*
- *to inform the workers concerned of the health risks their work involves,*
- *to apply Article 10 to female air crew.* » (Article 10: the dose to the fœtus should not be higher than 1 mSv during pregnancy)

French Regulation

Law (2001) and Decree of december 13th, 2003

- For each aircrew, the employer must:
  - *Carry out a provisional evaluation of the dose*
  - *Evaluate individual doses if > 1mSv/year with a method validated by IRSN, which could be computational.*
  - *Evaluation must take into account usual and exceptional solar activity*
- The occupational health doctor provides the individual medical monitoring
- Individual doses are kept by IRSN

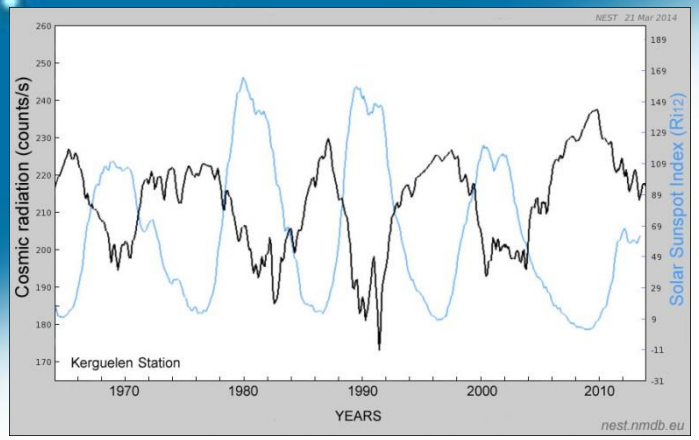
ICRP: International Commission on Radiological Protection included exposure to radiation from natural sources in its radiation protection recommendations in 1991

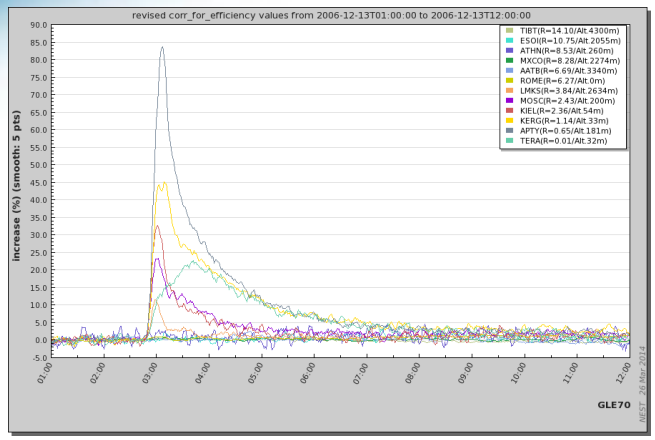
Partnership

SIEVERT system goals

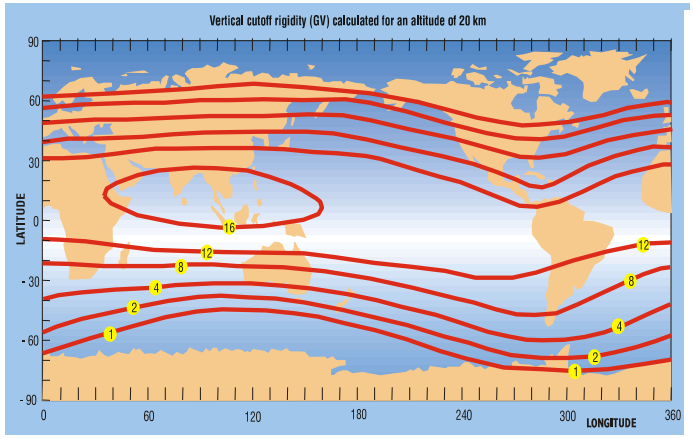
- Build an **operational** and **automatic** system for airlines
- Use **real flight parameters** to compute the dose
- Take relevant **Solar proton events** into account
- Propose a system **accepted** by stakeholders
- Provide an estimation of the dose and information to the public

Dose variation main factors

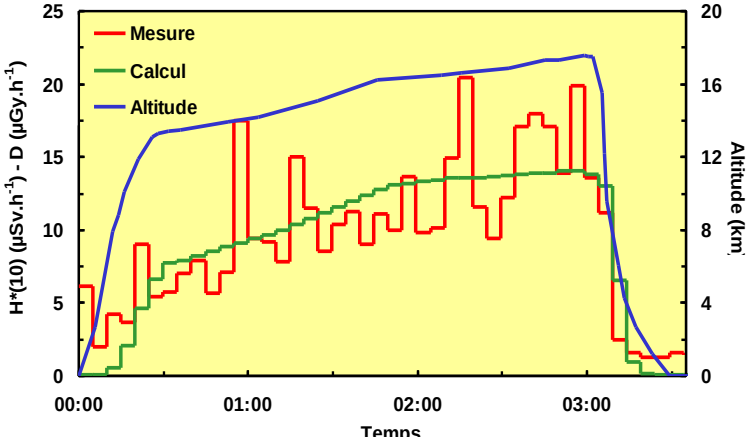




- Solar cycle and activity



Latitude (cutoff rigidity)

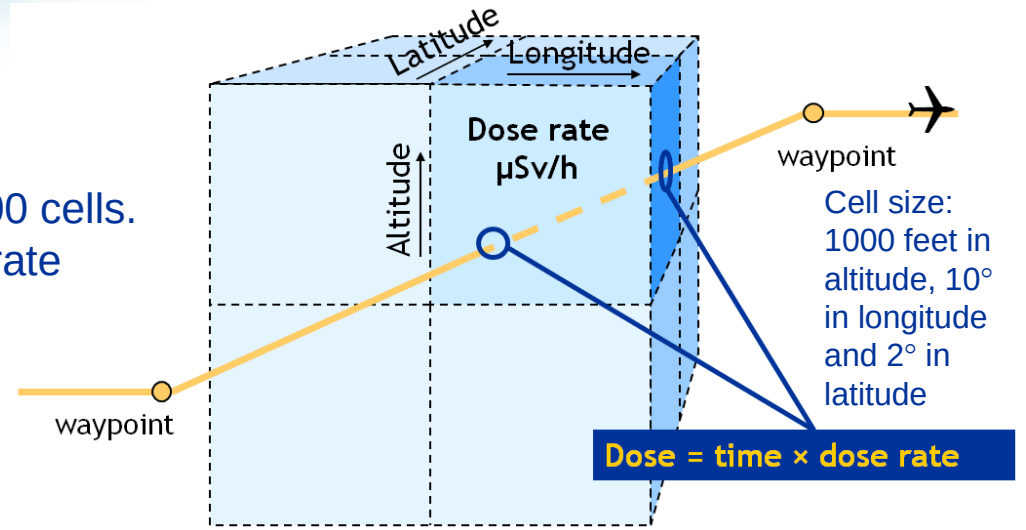


Altitude

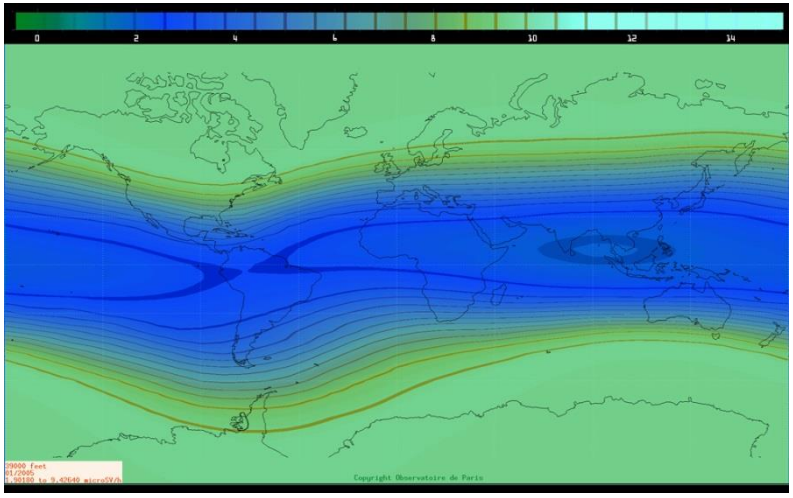
- Flight route
- Flight duration

Sievert Concept

Airspace is divided into 265000 cells.
Each cell is assigned a dose rate



The dose rates are computed with EPCARD model (Helmholtz Zentrum) every month



SIEVERT

Airline Flight file
- Flight Identification
- Date
- Aircraft type
- Departure point
- [waypoints...]
- Arrival point

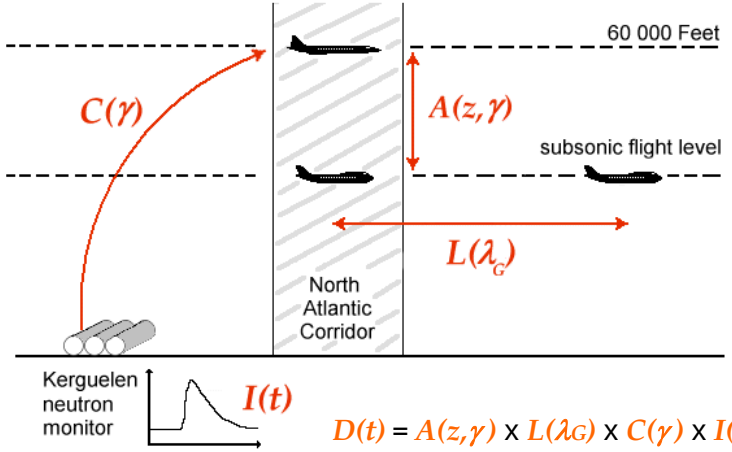
Doses/flight file
- Flight Identification
- Date
- Aircraft type
- Departure point
- [waypoints...]
- Arrival point

+ Dose received during the flight

SiGLE model

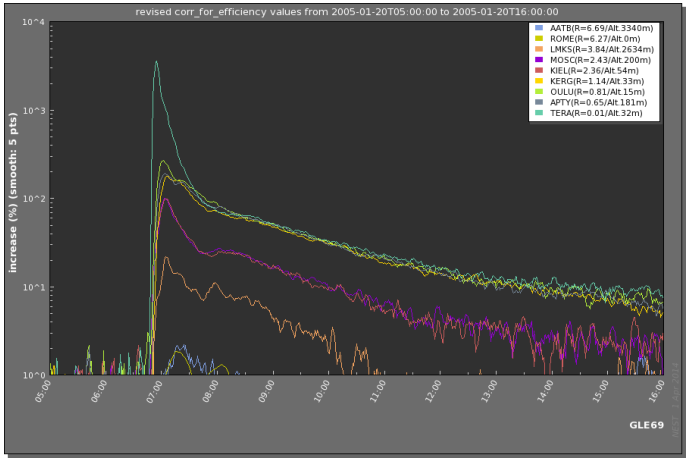
EPCARD computes doses for GCR, not solar particles => SiGLE

SiGLE is a semi-empirical model based on measurements onboard Concorde aircraft during past GLEs and results of numerical models. SiGLE computes doses in the case of a Ground Level Event

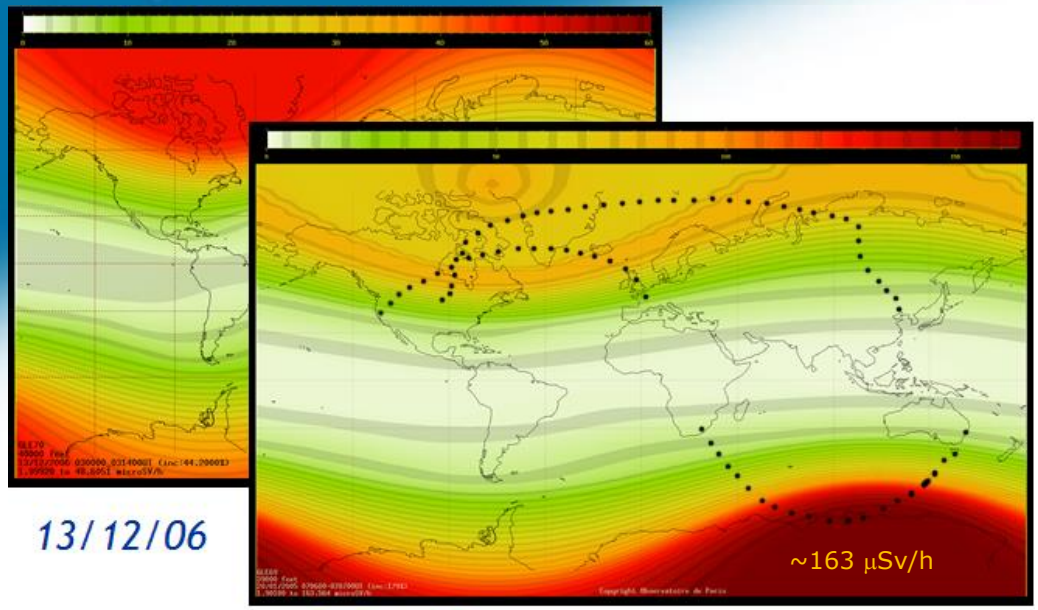


$D(t) = A(z,\gamma) \times L(\lambda_G) \times C(\gamma) \times I(t)$

The GLE information (intensity profile, spectrum) is given by our reference neutron monitor (Kerguelen station) and by the worldwide network of NMs. The data can be accessed using the NMDB (www.nmdb.eu) database interface: NEST (nest.nmdb.eu)



SiGLE



4 GLEs taken into account within SIEVERT (i.e. doses computed for aircrews): *14/07/00, 15/04/01, 20/01/05 et 13/12/06*

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FRSD                    CONSULTATION  PN/DOSE                  05/09/05  08:42:48
                                                                                1  F

MATRICULE :   33718513
NOM :  SC[redacted]          PRENOM :  CE[redacted]          FONCTION :  STEWARD/HOTESSE

DOSES ANNUELLES (MILLI SVT) :
2001 : 00,7166      2002 : 01,1812      2003 : 02,4880      2004 : 03,5711
ANNEE EN COURS :  01,3027  +  ERUPTION SOLAIRE
                    24 DERNIERES DOSES MENSUELLES
01 / 2004 : 00,3052                 01 / 2005 : 00,3600 ERUPTION
02 / 2004 : 00,3127                 02 / 2005 : 00,1858
03 / 2004 : 00,3634                 03 / 2005 : 00,2880
04 / 2004 : 00,2545                 04 / 2005 : 00,2927
05 / 2004 : 00,1751                 05 / 2005 : 00,1762
06 / 2004 : 00,3323                 06 / 2005 : 00,0000
07 / 2004 : 00,4411                 07 / 2005 : 00,0000
08 / 2004 : 00,1680                 08 / 2005 : 00,0000
09 / 2004 : 00,3096                 09 / 2005 : 00,0000
10 / 2004 : 00,4036                 10 / 2005 : 00,0000
11 / 2004 : 00,2756                 11 / 2005 : 00,0000
12 / 2004 : 00,2300                 12 / 2005 : 00,0000
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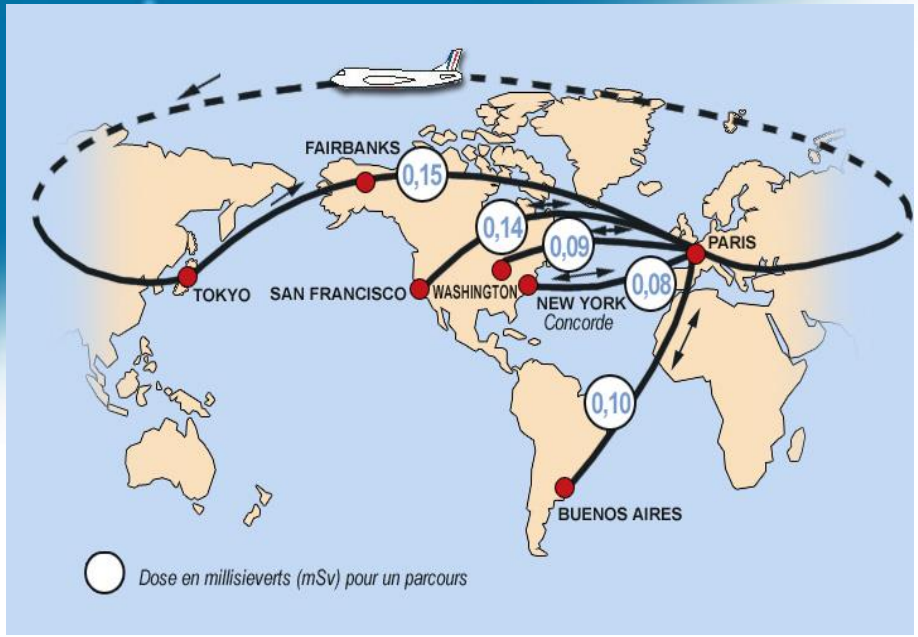
Route	Dose received from GLE 69 (µSv)	Dose received from GCR (µSv)	Total dose (µSv)
Chicago - Beijing	36.2	66	102.2
San Francisco - Paris	103	62.3	165.3
Sydney - Johannesburg	69.5	70.9	140.4

Validation of the doses



Mesures between 1996 and 1998 with the Hawk TEPC

Doses are validated by IRSN with different devices which are installed aboard AF aircrafts.
A new measurement campaign specifically dedicated to GLEs is ongoing (from jan/2013) :
-> 20 B777
-> 5 A380
-> 2 flights/day
-> 5 Liulins (Si-spectrometer)
-> 25 EPDN-2 (« basic » dosimeters)
-> Hawk TEPC for calibration

The Tissue Equivalent Proportional Counter (TEPC) measures radiation dose in complex radiation fields (fields containing a mixture of particle types)

EPDN2
gamma and neutron dose, data stored every for every dose increment, scanning rate 1 min

LIULIN
energy deposited spectra in Si and D(Si) rate

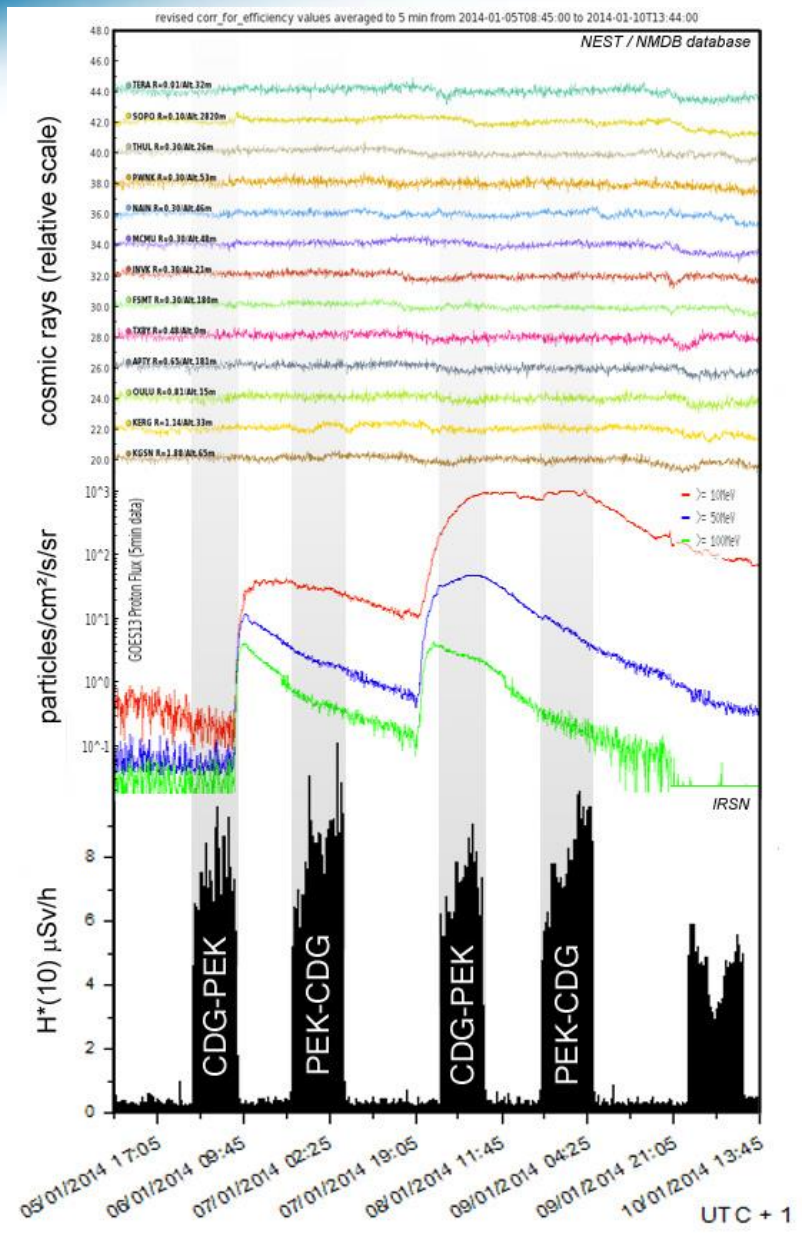
HAWK TEPC
“Gamma” dose is calibrated vs low LET component from TEPC and “Neutron” dose vs high LET

Measurements during solar events

In flight measurements during recent SPE tend to show that even in the case of a big proton flare, the dose may not be higher. Our approach is to compute doses only if neutron monitors show a significant enhancement.

Flight	Date	H*(10) (µSv) Measured	H*(10) (µSv) Calculated SIEVERT
Paris-Beijing	25-26 Dec 2013	48.6	48.6
Paris-Beijing	7-8 Jan 2014	49.6	50.0

Example of comparison of measured and calculated Ambient Dose Equivalent before and during SPE of january 2014 using Liulin dosimeters

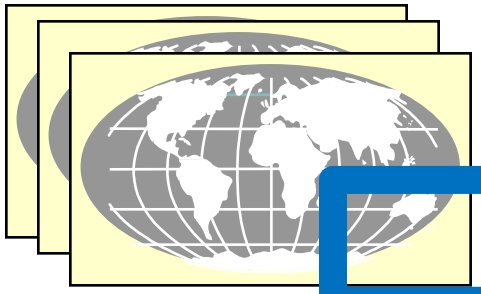


Operational Summary: Sievert system

Models
EPCARD

Data
Validation

solar Flares
SiGLE Obs. Paris



Dose rate
maps µSv/h

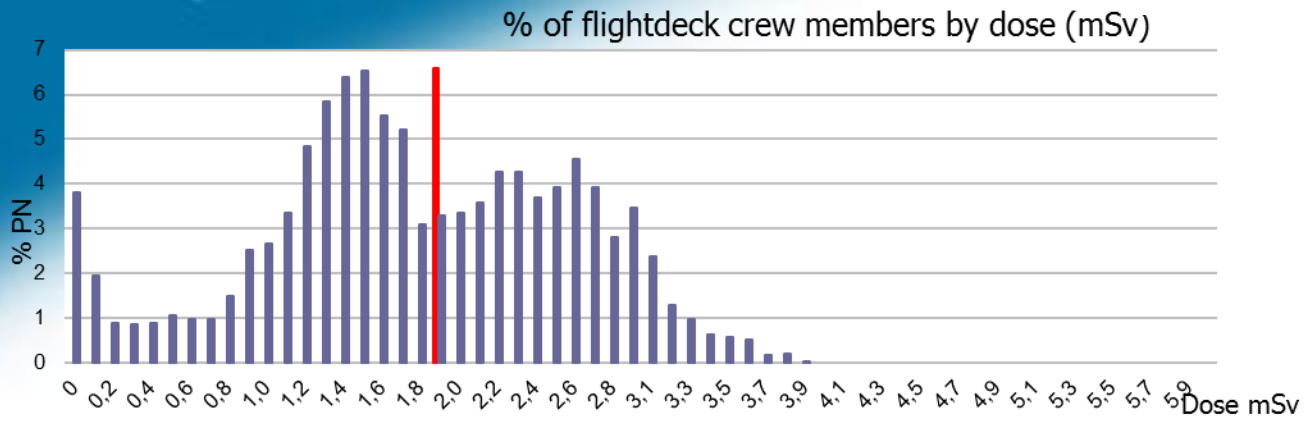
Airline Flight file
- Flight Identification
- Aircraft type
- Date
- Departure point
- [waypoints...]
- Arrival point
- **+ Dose for this flight**

Crew member flight file
- Flight identification
- Name of crew member

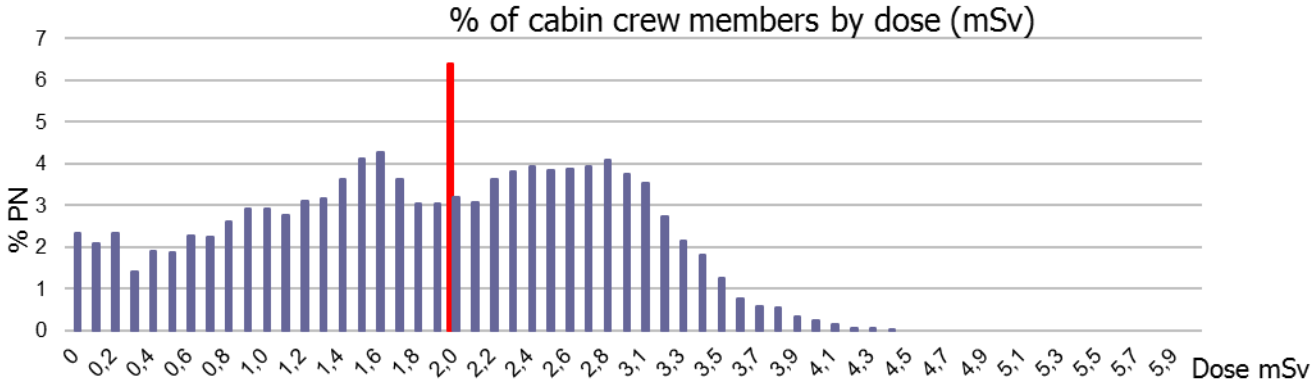
Crew member dose file
- Flight identification
- Dose
- Name

SISERI

Operational summary: AF data for 2012

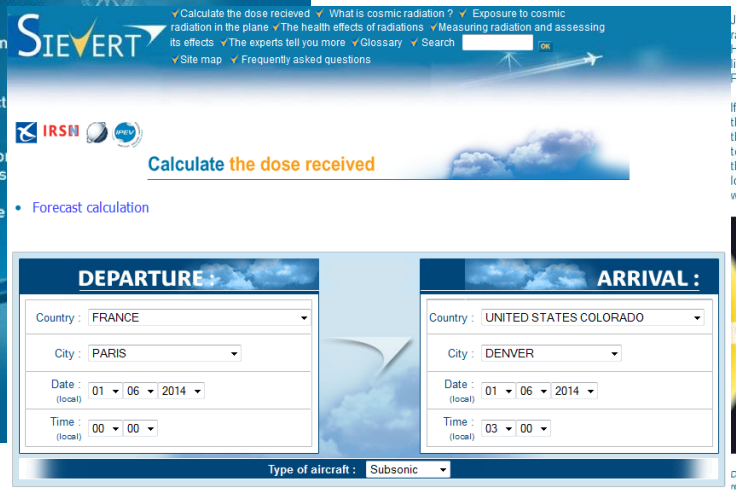


All crew members below the 20mSv/year limit



SIEVERT

website : www.sievert-system.org



Protection of the magnetosphere

Just like all electrically charged particles, the ions which are included in the cosmic radiation are directed or deviated by magnetic fields, as in the hands of a compass. However, the Earth acts as a huge magnet surrounded by a magnetic field, with lines of force which "enter" by the North Pole, and eventually "exit" by the South Pole: this is what is known as the magnetosphere.

If the cosmic particles possess energy which is greater than a certain threshold, i.e. the magnetic cutoff energy, they will cross through the magnetosphere and reach the upper layers of the atmosphere. But if their energy is insufficient, they will have a tendency to follow the magnetic lines of force, with which they more "easily", due to their lack of energy, succeed in reaching the poles. It is the reason why the areas located near the poles receive radiation in higher quantities than near the equator, which is better protected by the earth's magnetic field.

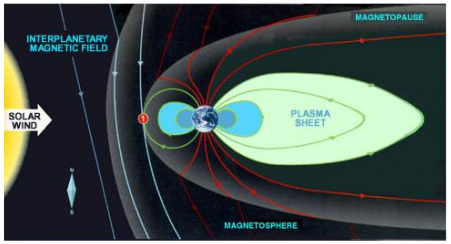


Diagram of the magnetosphere, which protects the Earth from the effects of solar wind. The sun, in reality much further away, is to the left of the figure. It constantly emits a flow of particles, the solar wind, which runs into the Earth's magnetic field. The geometry of the very structurally complex magnetosphere is altered by major solar flares. In certain cases, the magnetic field of the solar wind

Online since march 2002, new version under development

Key figures

- Operational since 2000
- 50/60 000 flights handled each month
- 30 airlines with an account (16 Fr –> 23000p)
- 4 solar flares taken into account

  14/07/00, 15/04/01, 20/01/05 et 13/12/06
- 1700 hits/month on the website